International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 9 Issue 11 November - 2025, Pages: 72-84

Climate Change and Community Resilience: The Frontier Options for Man

Tambe[1*], E.B.; Mbuka-Nwosu[2], I.E.; Agbe[3], E.; Evuen[4], U.F.; Etaware[5], P.M.; Okpoghono[4], J.; Oriomah[1], C.; Essaghah[6], A.E.A; Adinkwu[5], O.M; Enow[7], T.H; Okafor[8], N.M.; Asano[9]; N.O.; Nwakaji[9], K.N.; Jaff[10], V.S.

[1]Department of Environmental Management & Toxicology, Southern Delta University, Ozoro, Nigeria.
[2]Department of Environmental Management, Federal University of Technology, Owerri, Nigeria.
[3]Department of Environmental Management, Southern Delta University, Ozoro, Nigeria.
[4]Department of Biochemistry, Southern Delta University, Ozoro, Nigeria.
[5]Department of Plant Science and Biotechnology, Southern Delta University, Ozoro, Nigeria.
[6]Department of Urban and Regional Planning, Southern Delta University, Ozoro, Nigeria.
[7]Africa Climate and Environment Foundation (ACEF), Limbe, Cameroon
[8]Department of Environmental Management, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria.
[9]Department of Geology, Southern Delta University, Ozoro, Nigeria.
[10]Department of Geology, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria

Abstract *Charting pathways of improving human wellbeing is mainly contributing to enhanced greenhouse gas emissions. The review summarised the increasing emissions, challenging status of climate change and human wellbeing, and design a pathway for sustainability. Emissions of carbon dioxide, methane and nitrous oxide are altering long term patterns in precipitation, temperature and humidity of the earth – conditions jointly referred to as climate change. The interconnectedness of these alterations with human sustenance networks are causing inequality, poverty, water scarcity, food insecurity, ecosystem degradation and general human suffering. These outcomes are challenging the prospect of realising human goals and aspirations. However, the impacts of climate change are unevenly distributed; developing and poor countries are worst hit following their huge reliance on climate-sensitive livelihoods. This is worsening the existing challenge of these people to achieving sustainable development. Despite global effort to curb climate change, the average global temperature remains highest in the last decades, and its interconnected risks to communities are worrisome. Consequently, living with climate change remains the last frontier for man in his pursuit to continue living on the planet. This has necessitated 'living-with-climate' strategies that capture the networks sustaining man such as climate-resilient agricultural systems, building human financial capacities to accommodate climate shocks as well as integration of biomimetic designs in infrastructural developments. While technology and funds are needed to sustain these adaptation measures, challenging global peace, poor governance and cooperation is limiting those in need of these resources to access them. Consequently, bringing the global community to a platform of cooperation and peace will require designs that integrate a sense of interdependence in human existence and the need for humility in the human person. These pathways for achieving workable adaptation strategies have been addressed and are necessary if society seeks a just, prosperous and a more secured global future.*

Keywords: Climate change, resilience, adaptations, human humility, sustainable development.

1. Introduction

The earth's systems necessary to sustain life is mainly made of lithosphere, hydrosphere and atmosphere. The atmosphere is the gaseous component of the earth and it is in continuous interrelations with the other components, hence making the earth a dynamic and livable planet (Duarte et al., 2021; Santschi, 2023). In the lower layer of the earth's atmosphere lies the troposphere which contains 75-80% of the mass of atmospheric gases. Among other gases in this layer are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapour (Darkwah et al., 2018). These gases are called greenhouse gases and are so called because they provide a mechanism that maintains a livable climatic conditions (e.g. temperature) for life forms just like in a greenhouse – glass enclaved house designed to regulate temperature and humidity of the internal environment. Consequently, these gases are essential to maintain healthy, productive and livable planet through ensuring habitable climatic conditions (e.g. temperature, atmospheric pressure, wind, precipitation, humidity, cloudiness and ocean currents) for all life forms.

The mechanism of these gases (natural atmospheric greenhouse gases) is through providing a 'blanket' that allows ultraviolet radiation (short wavelength) from the sun to strike the earth, and the earth subsequently reflecting/emitting infrared radiation (long wavelength) into the atmosphere (Buha, 2016; Comsan , 2006). Some of the emitted infrared radiation from the earth is being re-radiated back to the earth by these natural greenhouse gases ('blanket'), while others diffuse into outer space. The re-radiated infrared radiation by the natural greenhouse gases makes the earth warmer and suitable to support interaction of myriad of life forms with abiotic components in the biosphere. This is called the natural greenhouse effect. This means without the re-radiated infrared radiation back to the earth by these natural greenhouse gases, the earth would have been too cold (between -18^{o}C to -20^{o}C), instead of the current average of 15^{o}C (Jacob, 2022; Lindsey & Dahlman, 2024;). The cold temperature condition is unsustainable for human

habitation and also challenging to support the myriad of life forms that we share the planet. Therefore, community wellbeing and sustenance network of life forms on earth is anchored on the regulatory mechanism of these natural greenhouse gases.

However, following increasing human numbers on the planet and the need to ensure human progress and wellbeing across the globe, there is growing effort by governments, organisations and goodwill individuals to charting pathways for the wellbeing of communities (Ryff, 2018; UNDP, 2019; Yavinsky et al., 2015). These pathways are usually through industrial development, widening settlements, road construction, institutional growth (hospitals, schools, public and private infrastructures), agricultural development and other needs of society. In the course of these development pursuits, there is utilisation of fossil fuels, alteration of ecosystems and practices that fail to capture the tenets of climate-smart procedures. The consequences of these are release of unhealthy substances into the environment, besides the greenhouse gases. The greenhouse gases released by these anthropogenic activities are adding to the natural greenhouse gases, hence increasing the concentration of these gases in the atmosphere. This increase in concentration of greenhouse gases impedes emission of reflected infrared radiation by the earth to outer space (enhancing re-radiation of infrared radiation back to the earth) and causing enhanced warming. This is termed enhanced greenhouse effect-causing average increase in the temperature of the earth and altering weather patterns.

While the natural greenhouse effect is essential in providing a livable climate for life forms, the enhanced greenhouse effect is altering climatic conditions of the planet and causing long- and short-term patterns in precipitation, temperature conditions and humidity of the earth – conditions jointly referred to as climate change. Climate change is altering agricultural production, degrading ecosystems, weakening fresh water availability, promoting floods and arid conditions in some regions of the world, exacerbating human suffering, poverty, inequality among others (Adamo et al., 2021). These conditions are interconnected and are weakening human achievement to all seventeen sustainable development goals. Consequently, addressing issues related to climate change have become central to environmental sciences and the global community.

Although there have been several efforts, international cooperation and agreements to curb the climate challenge, the average global temperature has been on a rising pace (UNEP and CBD, 2024; UNFCCC, 2024). The outcome has been worrisome, especially in developing economies that are worst hit, already suffering existing deprivations and are dependent on climate-sensitive livelihoods (MoALMC, 2018). While mitigation measures to climate change are providing useful pathways to curb the rising global temperature, adaptation strategies are providing new frontiers of opportunities to live with the changing climate (Hass & Wentland, 2024). These adaptation strategies include promoting agricultural technology whose productivity is not relegated by climate dynamics, strengthening availability and access to climate funding such as insurance in the agricultural system to accommodate climate-related shocks, and building infrastructures (biomimetic designs) that can align or adapt with the changing climate. These approaches have been well established and seem achievable. However, the challenges of realising them are rife.

This review, therefore, has established the status of climate change, its uncertain future and the role of polarised governments in worsening the climate challenge. It has employed cooperation among nations, good governance with nations and peaceful communities as a means to efficiently transfer technology and funds to regions vulnerable to climate change. In the midst of global differences across nations and their associated conflicts in some regions, this review designs new frontiers of opportunities that are required to bring the global community together, promote a ‘living-with- climate-change’ strategy with a view to achieving human goals and aspirations.

2. Research Methodology

The research employed keywords that revolved around the themes of climate change, community resilience with focus on adaptation in agriculture, funding and infrastructural designs. These keywords were used to conduct literature search from several data bases such as google scholar, springer, science direct, academia, research gate as well as publications from governments and international organisations. The search yielded relevant articles that capture the evolution of human activities, climate change and its associated problems; resilient pathways and the current status of the climate challenge. Based on the outcome of the search, and the complexity of the climate problem, an innovative design has been developed to chart the future of communities in living with climate change.

3. Achieving Sustainable Development in Climate Crisis

3.1 Evolution of Human Activities, Greenhouse Gas Emissions and Climate Change

Throughout human history on earth, activities tailored towards his wellbeing have been keenly considered in his pursuit for development (OECD, 2013). These activities include agriculture, production, transportation, construction, development of settlements among others. Prior to the beginning of industrial era, these activities were mainly carried out manually with less noticeable concerns on how they were altering the quality of the environment. Since the beginning of the industrial era in the late 1800s and early 1900s in Great Britain, there has been profound burning of fossil fuels, enhanced agricultural activities, alteration

of ecosystems, industrial development, and increase land utilisation to sustain society (Pirani, 2018). These activities and resource utilisation are aligned with increasing human numbers and the pursuit for better and desirable lifestyle.

For example, it took the whole of human history for human population to reach one billion in the year 1800, and in just 200 years later (the year 1999), the human population was six billion (United Nations, 2021). Twenty-five years later, the world population has passed 8 billion people, with significant rate of human population growth in developing economies. Also, there is increasing rural to urban migration by young people in pursuit for descent lifestyle and increasing consumerism (Tanle et al., 2020). In the pathway of human population growth and the pursuit of descent lifestyle, the activities of human sustenance network need to be maintained, with resultant unhealthy consequences on the environment. One of such consequences, for example, is the release of greenhouse gases (carbon dioxide, methane, nitrous oxide and chlorofluorocarbons) into the atmosphere (Kabir et al., 2023). The sources and proportion of release of the greenhouse gases vary with human activities (Table 1).

Table 1. Anthropogenic sources of greenhouse gases

Greenhouse gas	Source of emission	Percentage (%) of emission
Carbon dioxide	Burning of fossil fuels Destruction of	81
	forests	17
	Cement plants	2
Methane	Rice cultivation	30
	Domestic animals	20
	Burning of vegetation	17
	Landfills	12
	Natural gas	12
	Coal mines	9
Nitrous oxide	Burning of fossil fuels	43
	Use of fertilizers	25
	Burning of vegetation	25
	Cultivated land	7
Chlorofluorocarbons (CFCs)	Industrial activities	100

Source: (Kabir, et al., 2023)

Following the wide spread utilisation of fossil fuels in economies across the world and its subsequent release of carbon dioxide, the gas (CO_2), has been found to contribute 50% of increasing global temperature (Kabir et al., 2023; Zhong & Haigh, 2013). Consequently, CO_2 is central to the discussions and issues on greenhouse effect and climate change. This is followed by CFC_s (20%), methane (15%) and other pollutants (10%). Although methane contributes only 15% of temperature increase (due to its relatively lower number of emission sources), its global warming potential is about 25 times more than that of CO_2. Consequently, increasing sources of methane emission into the atmosphere are worrisome.

The contributions of these gases to the global planetary system, and subsequently causing climate change became of concern in the mid-20th century when data gathering on the levels of carbon dioxide in the atmosphere was correlated with the changing temperature (Kabir et al., 2023). Since then, data revealed that CO_2 levels in the atmosphere has been increasing, and was 316.8ppm in 1960, and this increased to 366.7ppm by the year 2000. By the year 2020, CO_2 concentration in the atmosphere had exceeded 400ppm (Lindsey & Dahlman, 2024; Wang et al., 2023). This trend in increase of CO_2 levels is estimated to reach 500ppm by 2040. This scenario of increasing CO_2 levels means that if the concentration is doubled as at the 1960 level, the average temperature of the earth will increase by 2^{o}C (IPCC, 2023; Wang et al., 2023). According to (Lindsey & Dahlman, 2024), the temperature of the planet has risen by an average of 0.06^{o}C per decade since the 1850, and 1.35^{o}C above the pre-industrial period of 1850-1900. The increasing CO_2 levels and its associated temperature has devastating interconnected effects on all aspects related to the wellbeing of society (sustainable development goals), ranging from sea level rise and its subsequent flooding, salinisation of freshwater supplies, erosion of beaches, ecological impacts, alteration of weather patterns and precipitation, agriculture, education, descent jobs, security, human wellbeing among others. This means sustainable development is anchored on a healthy climatic condition, and when development lacks the tenets of sustainability, it is being challenged by the same climatic conditions. This has necessitated the recurrent call for a healthy climate since the emergence of environmental concerns.

3.2 Sustainable Development and Community Wellbeing in Healthy Climate

After the end of the millennium development goals (MDGs) in 2015, the leaders from 193 countries of the world came together to define the future of the planet (United Nations, 2017). The MDGs registered some levels of success, although there were variations across regions, countries, states within countries and even across communities within the same states. Consequently, these leaders saw a challenging future; characterised with poverty, famines, drought, and plaques. These challenges were found not in a distant

country, but in their own communities, towns, and cities. Also, the leaders were aware that billions of people on the planet have a shared hope for a better and prosperous future. Based on this shared hope in a challenging planet, these leaders in their commitment to serve society, created a plan termed the sustainable development goals (SDGs). The SDGs is a set of seventeen goals to be achieved by 2030, with United Nation Development Program (UNDP) being the leader in this global movement.

These goals are: no poverty (goal 1); zero hunger (goal 2); good health and wellbeing (goal 3); quality education (goal 4); gender equality (goal 5); clean water and sanitation (goal 6); affordable and clean energy (goal 7); descent work and economic growth (goal 8); industry, innovation and infrastructure (goal 9); reduced inequalities (goal 10); sustainable cities and communities (goal 11); responsible consumption and production (goal 12); climate action (goal 13); life below water (goal 14); life on land (goal 15); peace, justice and strong institutions (goal 16); and partnerships for the goals (goal 17).

These goals summarily seek to ensure a world that would be rid of hunger, poverty, and safe from the devastating effects of climate change. Highlighting climate change in the summary highlight of all the seventeen sustainable development goals depicts its significance in influencing all the goals. (Anukwonke et al., 2022) showed that climate change is interconnected to all the sustainable development goals, and none of these goals stands in isolation. This means that in a healthy climate, communities will continue to be productive to meet their needs, resilient to the dynamics of the environment and sustainable for future generations (UNDP, 2019). On the contrary, when the climatic conditions are unhealthy, communities will be less productive, vulnerable and unsustainable.

For example, in a planet with healthy climatic conditions (goal 13), hydrological balance is sustained and water sheds will continue to provide the necessary freshwater to communities (goals 14 and 15). Community access to freshwater supply enhances good health, reduces expenditures on medical bills associated with poor sanitation, promote work force, strengthen agricultural production and income, and assist in addressing the challenges of poverty and human suffering (goals 1 and 8).

Similarly, a healthy climate ensures balance in the ecosystem through sustaining interrelations within biotic components and between biotic and abiotic components, promote soil health that is suitable to strengthen agricultural systems, increase productivity in farm produce, and possible harvesting of clean energy (bio-methane), increase on farmers' income and promote access to quality education for rural children, especially for rural poor whose main source of livelihood is agriculture (goals 4, 7 and 8). Enhancing access to education is related to technological advancement and building capacity to handle the myriad of complex challenges that face society (goal 9), open frontiers for descent jobs, reduce poverty, widen the corridors of economic growth and making the global community more prosperous (goals 8 and 9). When the income and wellbeing of communities are strengthened, inequality within a generation (intra-generational inequality) and inequality across a generation (inter-generational inequality) is reduced (goals 5 and 10). Also, increase in agricultural yields is aligned with reducing hunger (goal 2), strengthening calorific/nutrient intake of communities so as to enhance good health (goal 3). A suitable climate reduces disasters associated with climate and cause evolution of more livable and sustainable settlements (goal 11). In such settlements, clean water, better sanitation and reduced health challenge are guaranteed (goals 3, 6 and 8). A habitable climate will reduce community reliance on fossils fuels (unsustainable energy source) for air conditioning and fans, curb issues related to urban heat island, hence promoting a green economy (goal 12).

While the SDGs are attractive in making a habitable world for all, achieving them requires robust governance systems and institutions to promote partnerships, and ensure that citizens participate at all levels in decision making process (goals 16 and 17). Reliable institutions are essential to ensuring a holistic framework to handling excesses that could emanate from corrupt systems and subsequent disruption of the goals of climate attainment. Such institutions and governance system can facilitate the process of a market system that ensures externalities of goods and services from cradle to grave are captured or internalised into the cost of the goods (goal 12); promote equity and objectivity in allocation of resources; strengthen governance systems that demonstrate goodwill and expression of concern for tomorrow; promote gender parity and protects the vulnerable groups of society (goal 5). Therefore, a healthy climate is central to achieving all the sustainable development goals. Unfortunately, society is faced with the challenge of achieving these goals in rising global temperature. However, re-designing the pathways through which climate change affects the achievement of sustainable development goals is essential in providing leverage points to addressing the climate challenge.

3.3 Climate Change and Risks to Sustainable Development

While the healthy conditions of a global climate are essential in sustaining human wellbeing, the pathways of achieving progress in some regions of the world have been promoting unhealthy climate, hence degrading the basis on which sustainability is anchored. This is resulting to a vicious cycle that affects our planet and the survival of man (Anukwonke, Tambe, Nwafor, & Khired, 2022). For example, the inter-relations of natural resources (biotic and abiotic) is providing an anchor for life forms on the planet (Sintayehu, 2018). These include provision of shelter, temperature regulation, freshwater supply, clean air, soil preservation, enhancement of soil nutrient and subsequent provision of avenues for community livelihood (Langat et al., 2016). However, in the utilisation of natural resources such as forest to provide timber for development of society, the rate of harvesting the resource (deforestation) is exceeding its replacement (afforestation) globally. The outcome is reducing carbon sequestration and its concomitant implication on rising temperature. Rising temperature is promoting wild fires, drought, pests, invasive species and stressors that are reducing forest

productivity (Dale & Frank, 2017). In some regions, the rising temperature is causing the disappearance of indigenous fauna and flora, northward migration of species and subsequent emergence of new species. While the migratory species are facing the challenge of adapting to new environment, the invasive species bring and transmit new ill-health that adds to the misery of communities (Howard, 2019). Rising temperature also means increasing capacity of the troposphere to accommodate more water, hence adding the volumes of greenhouse gas in the troposphere.

Global temperature rise has been reported to disrupt the functions of aquatic ecosystems (Neelmani et al., 2019). For example, increase in CO_2 levels cause increase in temperature in aquatic ecosystems and increase in the level of acidity. Such aquatic conditions weaken the build-up of coral shells and alteration of food chains. Rising aquatic temperature also reduces oxygen levels in the aquatic environment. The result is reduction in fish population and the economy of fishing industry, increase in joblessness, and challenge sources of protein and food security. A reduction in fish population during period of expected seasonal abundance means a threat to the survival of migratory birds, and a distortion in the food chain and ecological balance (Xing et al., 2021). Rising temperature increases evaporation of freshwater bodies such as springs and streams, hence reducing their volume of water. The reduction in the volume of water in these water bodies means reducing their capacity of recharging wetlands and access to domestic water supply in communities. This reduces wetland coverage and a threat to aquatic flora and fauna, quality of water, access to water, sanitation and hygiene of communities, and affects the diversity of aquatic environment.

Also, rising temperature is leading to increasing decomposition of soil organic matter and subsequent emission of CO_2 into the atmosphere (Eglin, 2015). This process reduces organic carbon in soil, leading to poor agricultural yield. This is interconnected to challenges in food security, weaken health status of communities, reduce income for farmers, impedes farmers' access to basic needs and create a vicious cycle in society. Similarly, climate change is causing variation in precipitation patterns in some regions and subsequently flooding, loss crops, destruction of properties and infrastructures (Lyammouri & Bozsogi, 2024). The risks associated with climate change are not evenly felt across regions (Economic Commission for Africa, 2023). Developing and poor countries, whose sources of livelihood (agriculture) are climate sensitive are worst hit. A challenge to their agricultural systems weakens their survival networks, especially the rural poor – impeding them from accessing medical care, increase vulnerability to disaster, weaken access to educational achievement and generally poor standard of living as indicated in the multi-dimensional poverty status of these countries (UNDP, 2019).

Therefore, the risks of rising temperature or increasing precipitation are interconnected and affect all aspects of human strive to achieve sustainable development goals. There is no unique pathway of these interconnectedness. These range from variation in precipitation, such as increasing flooding and erosion, and how these conditions affect settlements, ecosystem, agriculture, water supplies, disruption of socio-economic and traditional-social network, injury, loss of lives, and human suffering to its influence on vegetation cover, crop growth and poverty. Linking climate change and its implications on soils, agricultural systems, food needs of society, poverty, human health, and access to education have been well established and remain worrisome to man (Anukwonke et al., 2022; Lyammouri & Bozsogi, 2024). These interconnected challenges have led to unceasing research on designing pathways to reduce emissions of greenhouse gases and designing systems that can accommodate and exist with the dynamics of the climatic conditions.

4. Resilient Pathways to Achieving Sustainable Development in Climate Crisis

Since climate change is mainly caused by anthropogenic activities through the pathways of achieving sustainable development, addressing issues of climate change require reviewing human pathways that are causing the challenge and designing systems that can accommodate and co-exist with changing climate. These human pathways that require reviewing are the processes that are leading to emission of greenhouse gases, and their review requires modelling, redefining the processes and conducting research with a view to reducing emissions and provide new insights, without jeopardising the ability to meeting the needs of society and sustainable development (Tambe et al., 2024). These pathways can be described as mitigation to climate change (Hass & Wentland, 2024).

Several mitigation strategies to reduce emissions and curb the devastating effect of climate change have been developed (Anukwonke et al., 2022; Tambe & Okonkwo, 2017; Tambe et al., 2023). These strategies range from agricultural sector such as use of renewable energy to reduce emissions of CO_2 and its related gases into the atmosphere; transforming farm wastes to wealth such as use of animal wastes and putrescible to produce bio-methane for use as cooking fuels and generation of electricity; drip irrigation in farmlands so that energy use to harvest groundwater is sustained; reducing food losses so as to curb emissions related to it; use of appliances in households and behaviours that reduces emissions; policies that moderate consumption behaviour such extended producer responsibility (EPR) and designs that curb emission of greenhouse gases. Agriculture alone contributes 19 to 29% of total anthropogenic greenhouse gas emissions (Crippa et al., 2021). This means huge contributions made through mitigations in the agricultural sector can assist immensely in curbing emissions and promote climate-smart agriculture (Crippa et al., 2021; UNFCCC, 2021)

On the other hand, designing systems that can accommodate and co-exist with the dynamics of climate change are frontiers of opportunities that look beyond mitigations. These are described as adaptation to climate change (Hass & Wentland, 2024). These adaptation strategies are resilient strategies to climate change - ensuring that the systems, practices and innovations in communities have the capacity to absorb shocks and perturbations while retaining its function, structure and adaptability (Hellman & Shandas, 2020). As the climate is likely to remain dynamic (an average of global rise in temperature and increasing precipitation in some regions), these resilient pathways remain central to the survival of man on earth. The pathways include but not limited to development of agricultural systems such as seeds and crops that integrate well in the dynamics of climate; infrastructural designs, technology and innovations that evolve with changing climatic conditions, provision of support systems to enhance farmers' resilience to climate related shocks among others. However, mitigation and adaptation (resilient) strategies are not mutually exclusive, hence should be addressed simultaneously. This section of the article examines the resilient pathways to achieving human goals and aspiration in rising temperature of our planet, with highlight on the agricultural systems, funding and infrastructural designs.

4.1 Achieving Climate Resilience in Agricultural System: Biotechnology and Funding

In the agricultural system, building climate resilience is applied in the science of biotechnology by developing seeds that can withstand the dynamics of the climate and the availability of invasive species and pests (Louwaars & Manicad, 2022). For example, seventy thousand (70,000) metric tonnes of drought-tolerant maize seeds was commercialised in thirteen countries in Sub-Saharan Africa in the year 2016 (Cairns & Prasanna, 2018). While the increase in drought-tolerant maize was done in these countries, obsolete varieties were phased out. The development of new seeds breed is done without relegating the cultural value of the food to communities while sustaining the level of production to meet the needs of society. Ensuring sustainable production in the agricultural sector will promote resilience to hunger, strengthen farmers' economic resilience and reduces poverty in agrarian communities.

Also, within the agricultural sector, there is growing interest and research in the application of climate-start agriculture in the quest for sustainability in agriculture and promotion of human wellbeing (Tambe et al., 2023). These include seeds and plants that can tolerate salinity due to climate change and salt-water intrusion, survive in water-stressed regions, resistance to diseases and pests, shorter growth cycles and high yields (Caldera et al., 2021; Klauser, 2021; Kumar et al., 2024). With such seeds and plants that accommodate these stressors, the tendency for utilising fossil fuel for extraction of groundwater for use in agriculture is reduced. This subsequently reduces greenhouse gas emissions (mitigation) and competing needs of fresh water in communities. Reducing competing needs for fresh water will promote access to clean water and sanitation, good health and wellbeing of communities. Thus, biotechnology and genetic engineering provide windows of opportunities to tackle the climate dynamics and sustain communities through climate resilient seeds, hence adding value to agricultural systems and reducing losses (Kumar et al., 2024; Loreto & Atzori, 2024). According to Cacho et al. (2020), benefits relating to adopting climate resilient seeds in sub-Saharan Africa are estimated to range between 0.984 billion and 2.1 billion United States Dollars (USD) between the years 2020 to 2050.

Furthermore, as soil tillage is essential for plant growth, it is also increasing methane emissions into the atmosphere (Valujeva et al., 2022). For example, in a study by Fiorentini et al. (2024) on soil tillage, greenhouse gas emissions and cereal yield in the Mediterranean, no soil tillage showed a higher crop yield than conventional tillage (+1.2t/ha) in favourable temperature conditions. Consequently, it is essential to develop and identify plant varieties that are resilient to less tillage and better yield. While ensuring less tillage of soil, promoting alley cropping, crop diversification and agroforestry can disrupt pest cycle that are associated with climate change (Barman et al., 2022; Siarudin et al., 2021). These different cropping types create microclimatic conditions for crops that are grown below shades of trees, hence reducing heat stress on the farmland and promote resilience of the farm (FAO, 2019). This is interlinked to the goals of better crop yield, achieving zero hunger, increase farmers' income, strengthen food security and sustain healthy communities.

Also, funding opportunities are new frontiers in boosting farmers' resilience in the agricultural sector as captured in the tenets of achieving climate-smart agriculture (FAO, 2019). Climate–smart agriculture (CSA) was introduced in the year 2010 at the Hague conference with the theme: Agriculture, Food Security and Climate Change (Klauser, 2021). CSA is anchored on achieving increased food productivity, enhanced resilience and reduced emissions. The tenets of enhanced resilience have been established within the confines of strengthening funding in agricultural projects in many developing countries, where countries such as Zambia, Congo, Kenya, Zimbabwe, Morocco, Ghana, Burkina Faso, Bangladesh, Mali, Lesotho and Cote d'Ivoire have benefited (FAO, 2019; World Bank, 2021a). Funding and insurance have significantly improved on reducing emissions (such as the use of energy-efficient and eco-friendly technologies, using renewable energy, transforming waste to wealth among others), increased yield and reduces farmers' vulnerability to climate shocks and risks (Madaki et al., 2023; Schaefer & Waters, 2016; World Bank, 2021). For example, when farmers make provision for insurance to their crops and climate related disasters strike, provision of insurance will assist these farmers to bounce-back to sustain food security in their households, reduce poverty and inequality, access good health, sustain mental health, access to education and descent jobs, promote economic growth and purchase new seeds among others.

4.2 Achieving Climate Resilience in Infrastructural Designs

Human infrastructures such as transportation, telecommunication, settlements, and energy among others are being severely affected by the impacts of climate dynamics. Developing climate-resilient infrastructures improves on service provision to communities, protect assets returns and increase the asset life (OECD, 2018). In order for communities to facilitate the implementation and development of climate resilient-infrastructures, there is a need to strengthen the enabling environment that promotes climate-resilient infrastructure. These include but not limited to access to information, encouraging investments that capture resilient infrastructures and widen the frontiers of awareness on climate-related risks.

With regards to access to information, high quality information, reliable and consistent data, and capacity to utilise this information can better inform planning. For example, identifying areas vulnerable to climate disaster through information is essential to redirect developments from such areas and building resilience in communities. Online tools and platforms are required by decision makers to provide transparent and credible information on past climatic conditions and projections for the future (McBean et al., 2021; Taylor, 2019). This information is gathered over a long period of time, such as 20 years or longer and they describe conditions of specific locations. The information can be long-term (10-50years) such as decadal changes, medium-term (3-9 years), weekly and monthly weather forecast (7-30 days), and daily forecast and observations (0-7 days). The available information should be utilised alongside institutional and technical capacity to manage these climate-related risks.

With available information, encouraging green-based infrastructures or mimicking natural designs can strengthen flood defenses, ensure water storage, energy savings and sustain crops and livestock in communities (Benyus, 2002; Tambe et al., 2023). There is growing interest and integration of the science of biomimetic architecture in infrastructural designs (Othmani et al., 2018). The science of biomimicry is premised on developing infrastructures that mimics the natural system and their abilities of utilising just what they need and self-regulating – resilient systems (Zari, 2007). These infrastructures can be categorised to function at three levels: organism, behaviour and ecosystem.

When an infrastructure is developed to function at the organism level, it examines the behaviour of that organism and how it is capable of surviving in its environment. An example is the Gherkin Tower in London that mimics how the Venus flower basket survives underwater current (Ehsaan, 2010). This means designing buildings that can resist fluid movement related to climate will reduce damages of resources vital for human wellbeing. This will save reconstruction cost associated with climate-related disaster and strengthens resilience of communities. An infrastructure can function at the behaviour level by mimicking how a natural feature interacts with its environment and promote energy savings- much needed resources during rising temperature in communities, hence energy resilience. For example, infrastructures to mimic the natural functioning of the termite mounds whose internal temperature is regulated by its internal mechanism to be between 21ºC and 25ºC no matter the unhealthy climatic condition of the external environment (Aiki et al., 2019; Pawlyn, 2011). An example of an existing infrastructure with such design is the Eastgate Center, Harare, Zimbabwe.

The ecosystem level of infrastructural designs is the most advanced and encouraged climate -resilient designs following their potential of regulating itself (resilience) in relation to the circumstances of the wider environment. The infrastructure mimics the natural processes and follows the principles of ecosystem services such as optimising the system rather than its elements, reliance on sunlight, adapt and evolve at different levels and develop conditions necessary to sustain life (Unvan & Erbaş, 2019). An example of an ecosystem design can be seen in Lavasa in India, a proposed 8000-acre city. The current climatic condition of the area is its regular subjection to monsoon flooding. However, data gathered revealed that the original ecosystem was moist deciduous forest before developing to the current arid landscape. In order to develop a resilient settlement to cater for the seasonal flooding condition, the foundation of buildings is designed in a way that they store water like the original trees did in the natural ecosystem of the area. For the buildings' roof top, they are designed to mimic the powerful drip system of banyan fig leaf - allowing water to drip off and at the same time cleaning itself (Gendall, 2009). The procedure to remove excess water in this city development project is borrowed from the design of local harvester ants which utilise multi-path channels to discharge water away from their nests.

Also, creating awareness and giving communities access (those really in need of the resources) to resources to cope with climate dynamics enhance resilience (OECD, 2013). Giving communities the appropriate tools, resources and knowledge, especially those involved in climate sensitive livelihoods can boost the resilience network. In developing and poor countries where agriculture is the major livelihood support system, empowering communities in this sector is essential in enhancing resilience (CRED & UNISDR, 2017). Also, identification of the rural poor, and vulnerable groups such as women, the girl child and elderly need to be well captured in the resilient-decision-making pathways. No one should be left behind. The cost of investment in resilience is six times lower than the losses associated with disaster in developing countries (United Nations, 2019). Although climate change is a global issue, there is no unique solution. While there are global and widely acceptable standards to tackle climate issues, approaches to strengthen resilience of communities will require local priorities in ways that integrate system thinking (Liu et al., 2018). Such system thinking requires designs that have reduced tradeoffs and productive synergies in achieving human goals.

4.3 Challenges and Prospect of Achieving Climate Resilient Communities – What then Shall We Do?

Achieving climate-resilient communities (living with climate change) in the quest for sustainable development is possible, but quite challenging (Figure 1). To muddle through these challenges, the steps conceptualised from "a" to "h" in Figure 1 has been proposed. In a world where variation to access to information, technology and economic potential of communities exist, there is variation in performance to achieving resilience to climate change in various sectors and communities (Garrido & Wyber, 2024; Climate Change Advisory Council, 2024). While technology transfer and resources are essential to building climate resilience in communities, partnership between nations as captured in the sustainable development goals is vital (United Nations, 2017). Absence of cooperation between nations, organisations and governments impedes transfer of resources and technology to those who are really in need (developing and poor nations). In recent decades, there has been national, international and regional conflicts such as that between Russia and Ukraine, conflicts in the Middle East (Israel against Palestinian Hamas and Hezbollah; Yemen conflict, Syria War), West, Central Africa, and East Africa such as internal conflict in Sudan and many other regions of the world.

There is also growing alliance of nations such as the alliance between Russia, North Korea, Iran and Hezbollah; and that between United States, United Kingdom, Israel and European countries. These alliances are creating a polarised world, worsening global cooperation and increasing vulnerability to conflicts. These tensions and instabilities are disrupting the global administration, linkages and the flow of technology and resources that could assist communities to adapt to climate change (Gopinath et al., 2024; Johnson, 2024). Following these disruptions, the relevance of the concept of globalisation is being challenged. Consequently, they continue to make communities who are really in need of resources become more vulnerable to climate related disasters and impedes achievement of sustainable development goals.

Even when the resources and infrastructures are made available, there is usually the challenge of peace, justice and strong institutions to sustain them. Achieving climate resilient communities requires governance system that expresses and have good intentions for communities and their wellbeing (Reddy, 2019; Stojanović at al., 2016). This is aligned with (Wapner & Mathew, 2009) who maintained that only when humans have deep concern for one another and transfer that inherent care to the environment, will we realise a healthy and productive environment. This means governance systems should promote and establish strong institutions that encourage cooperation between the citizenry and the public sector. This is central to achieving a just, productive and a secured global future. Unfortunately, these resources necessary to strengthen residents who are reliant on climate-sensitive livelihood do not really have access to them. When communities are frustrated with the challenge of sustaining their livelihood, poverty, insecurity, and general human suffering steps in and creates a vicious cycle.

Faced with the complexity of climate change in a polarised world, defining the future we want requires communities, governments, and organisations to come together and understand that we share a common life boat (planet earth). This means whatever happens to one part of the planet such as environmental degradation due to poor climatic conditions also affects the wellbeing of residents in other parts of the planet. For example, when residents in communities degrade forests and forest resources in developing and poor countries due to loss or weakening of their livelihood sources (agriculture, for example) following climate related disasters, the ability of the forest to provide carbon sequestration services for carbon produced in nearby communities is reduced. This adds to the global climate crisis and weakens our survival network in the life boat. Therefore, it is only when polarised communities start reducing their polarity through the intervention of mediators and friends of polarised nations will we achieve sustainable development. Also, intra-government institutions need to adopt a sympathetic and respectful approach towards each other, governments need to promote environmental education and the philosophy of human interdependence. These philosophies of goodwill and interdependence as a foundation for our continued existence are pivotal if we seek resilient and sustainable communities.

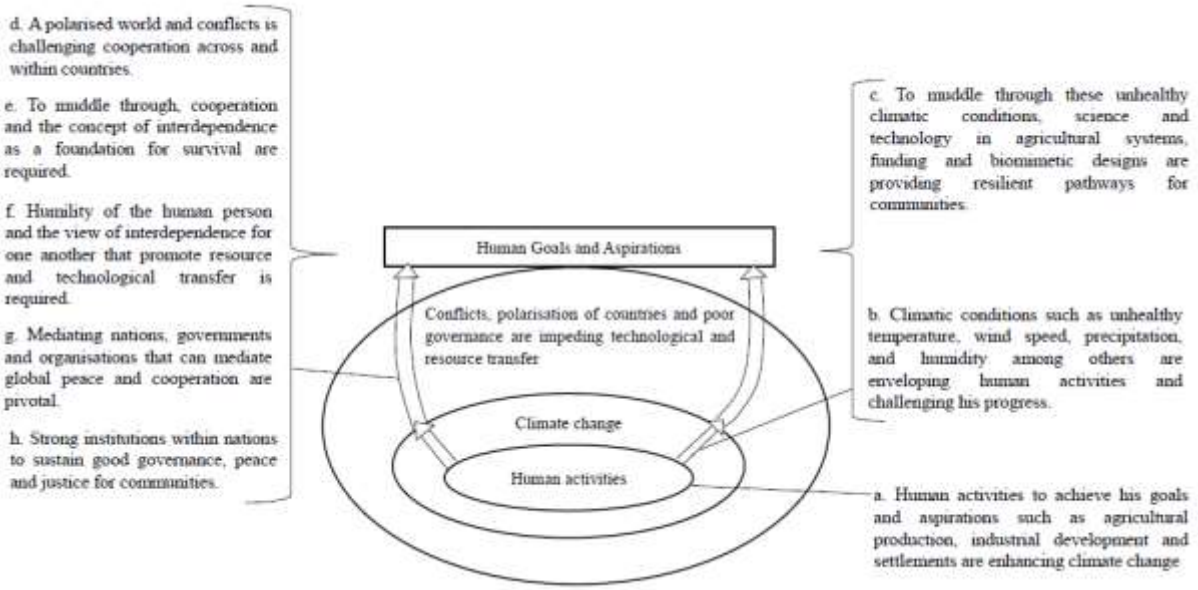

Figure1. Achieving human goals and aspirations in climate crisis and a politically polarised world.

5. Conclusion

Never has the global community come together to battle with climate change when compared to recent decades. Projection of the global climate reveals that subsequent decades could be less healthy than what we are experiencing, despite global efforts and research that are tailored towards saving our communities from this eminent danger that affects all elements of human survival. Consequently, humanity is faced with only one option - designing resilient pathways of living with climate change. These pathways include redesigning agricultural systems such as using the science of biotechnology, strengthening climate funding to accommodate shocks and promote the utilisation of biomimetic designs in infrastructural planning and development. These adaptation strategies are evolving. Despite these global innovations, its transfer and implementation across the globe, especially in worst hit climate regions are being challenged due to differences across nations such as conflicts. This last frontier of opportunity to save our planet and sustain human wellbeing requires designs that foster global cooperation and goodwill. These designs should capture elements such as recognition of the human person and interdependence on one another as vital indicators for sustainability. However, there is no unique solution, but local priorities to build resilient communities need keen consideration of relevant indicators while addressing this global challenge within a system perspective.

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